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Syconium-wasp association and ornithochory in Indian Bat Fig tree, *Ficus amplissima* Sm. (Moraceae)

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ABSTRACT

Ficus amplissima is a semi-deciduous monoecious tree species. The syconium-wasp association characterizes obligate mutualism and its breakdown affects sexual reproduction in both tree and wasp species. Figs are purple or red and attract only birds in the study location. The figs ripe during dry season when most of the co-occurring tree species are leafless or in flowering. At this time, the figs of this tree species provide food for bird fauna of different families and orders and these birds are involved in effective seed dispersal across the entire deciduous forest ecosystem of the study area. Therefore, *F. amplissima* is most likely a keystone species for birds utilizing its figs during dry season. The study recommends to take steps for planting this tree species in this ecosystem in order to sustain frugivorous birds during dry season.

Keywords: *Ficus amplissima*, syconium, agaonid wasp, seed dispersal, birds.

1. INTRODUCTION

Ficus is a genus of Moraceae family distributed mainly in tropical and sub-tropical latitudes (Chew 1989). In this genus, an extreme obligate nursery mutualism is functional with pollination effected by Agaonidae wasps (Cruaud et al. 2010). In this genus, each species is pollinated by a particular agaonid wasp species because the syconium of each species is suitable for breeding for particular wasp species (Bronstein 1992). The inflorescence is an urn-shaped syconium which encloses completely several to thousands of unisexual flowers. Since all flowers are enclosed, pollination by wind or common insect species is totally precluded. Further, selfing is not possible due to maturation of female flowers long before the maturation of male flowers. In this situation, a unique association between syconia and a tiny wasp family, the Agaonidae is evolved. Individual fertilized syconia act as hosts to a number of wasps of a particular species of Agaonid family. Each individual wasp develops separately in one ovary of the syconia. Female wasps emerge from the ripe syconia already pollinated and fertilized by short-lived wingless males. These wasps carry pollen load sprinkled on them or collected by them from the synchronously maturing male flowers and fly to syconia displaying earlier stage of development either on the same tree or a different conspecific

tree. Once land at the syconium, they force their way through the apical ostiole (opening into the syconium) to reach the flowers inside and in this act, they lose their wings. After reaching the flowers, they lay eggs in ovaries of female flowers while pollinating the latter and soon die inside. In this way, *Ficus*-wasp mutualistic association is inter-woven and any breakdown in this association is detrimental for both partners.

Janzen (1979) reported that *Ficus* genus is a keystone mutualist for many vertebrates in the tropical rain forest. Leighton and Leighton (1983) documented that fig fruits being abundant and available throughout the year constitute an important food source for many frugivores when other food sources are not available or scarce. Lambert (1991) noted that *Ficus* relies heavily on frugivores for their seed dispersal. Hamilton (1999) mentioned that seed dispersal by frugivorous animals guarantees long-term survival of many species of *Ficus*.

Fig species are considered to be keystone species for frugivorous animals in several forest types because their year-long flowering and fruiting ensures them a continuous availability of food source. The frugivores include birds, bats and small vertebrates which act as seed dispersers but some of them may act as seed predators (see Patel et al. 1993). In birds, the traits such as narrow gape, lack of teeth, a poor sense of smell, tetra-chromatic vision and feeding on fruits while perching characterize bird-syndrome fruits. The fruits of this syndrome display the traits such as small size, soft nature, visually prominent by color, lack of odor and their presentation among foliage along branches (van der Pijl 1969; McKey 1975; Janson 1983; Bowmaker and Hunt 2006; Bennett and Thery 2007). Bat characters such as nocturnal feeding, the presence of teeth, piecemeal style of eating fruits, clear sense of smell and taking fruit either in flight mode or after crawling to reach fruits are important for bat-syndrome fruits. The fruits in this syndrome are relatively large, hard, visually not prominent by color, presence of odor and their presentation along the trunk or away from foliage (Kalko et al. 1996; Korine et al. 2000; Elangovan et al. 2001; Mikich et al. 2003; Hodkison 2007). Fruit traits evolve in concert with differences in perceptive ability, behavior and morphology of their frugivorous seed dispersal animals. The differences among frugivores shape the evolution of fruit traits (Jordano 1995). With this backdrop, the present study is an occasion to report on syconium type of inflorescence and its association with particular agaonid wasp, and seed dispersal agents in *Ficus amplissima*, a large semi-deciduous tree species. It is a naturally distributed in Central and South India, Sri Lanka and Maldives. This species is quite abundant in Andhra Pradesh, Telangana, Tamilnadu, Karnataka, Kerala, Maharashtra, Goa (Chaudhary et al. 2012).

2. MATERIALS AND METHODS

Ficus amplissima trees growing naturally in the deciduous forest ecosystem of Kadiri Reserve Forest, near Alampur in Anantapur District in the southern Eastern Ghats of Andhra Pradesh, were used for the present study during February-May 2021. Leaf flushing and flowering occur in succession during wet season and fruiting by display of ripe fruits occur during dry season. The floral aspects were carefully studied to record the sexual system and function of inflorescence which is called as syconium with reference wasp pollination as this form of obligate mutualism is unique in the entire genus *Ficus*. The fruit development and ripening time was recorded and the animals that visit the fruits for food were also documented. The fruit collecting behavior and their role in seed dispersal nearby and far away from the parental tree were carefully observed for documentation. The field observations were analyzed to describe the role of birds as seed dispersal agents for *F. amplissima*.

3. RESULTS AND DISCUSSION

Ficus amplissima is a monoecious tree species. The leaves are simple and broadly ovate with an acute tip. The flowering and fruiting events take place during September-January. The inflorescence is an urn-shaped syconium consisting of a few male and numerous female flowers apically covered by an ostiole formed by bracts. The male flowers are borne near the ostiole while female flowers are borne in the interior lining the inside of the syconium. The female flowers display variation in style length and based on this trait, they are classified into long-styled and short-styled female flowers, each fertilized flower of the former type produces a single small 1-seeded hard-shelled achene. Many such achenes are produced which are enveloped by the fleshy tissue within the syconium. The short-styled flowers do not participate in fruit formation but individuals of particular agaonid wasp species use them as egg-laying sites during which they pollinate long-styled flowers. These flowers then become a mass of abnormal pulpy plant tissue and for this reason they are designated as “gall flowers”. The wasp larvae after emergence from these flowers feed on this gall tissue. Wingless male wasps emerge first and inseminate the emerging female wasps; then male wasps bore tunnels through syconium for the winged female wasps to take exist. The emerged female wasps collect pollen from the male flowers inside the same syconium and fly off to find receptive female flowers to repeat their life cycle. This characteristic obligate fig-wasp association is unique and common in *Ficus* genus which is highly speciose in occurrence (Berg and Corner 2005). It is pertinent to state that the fig inflorescence does not permit different wasp species of the same or different families for either breeding or feeding. However, *Ficus*

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species act as keystone species to provide food in the form of ripe fruits or figs to numerous invertebrates and vertebrates (Shanahan et al. 2001; Harrison 2005).

Schupp (1993) reported that animals must act as effective seed dispersal agents which in return obtain nutriment (fig pulp containing numerous small seeds) in advance for the function of mutualism between *Ficus* species and frugivorous animals. The effectiveness of seed dispersal relates to the quantity of seeds dispersed by individual species of frugivores and the number of visits paid by them to a fruiting fig tree. Janzen (1979) contended that figs are important resources for more animals than the fruits of any other genus/genera of other families. Globally, birds eating figs are parrots, pigeons, starlings, crows and allies. New World monkeys and fruit bats also eat figs in addition to these families in the Neotropics. Bulbuls, starlings, hornbills, Old World fruit bats, Old World monkeys, African barbets, Asian barbets and squirrels are other major fig eaters in the African and Indo-Australian regions. Fig eaters are classified into generalists, specialists and casual consumers. Specialist fig eaters are highly reliant on figs as nutrient resource for part of the year or year-long; primates, Agapornis lovebirds and fruit bats are additional fig specialist eaters in Africa. Specialism by animals on figs is reported to be more widespread situation in the Old World than in the Neotropics (see Shanahan 2000). Such a widespread phenomenon of specialist fig eaters in case of birds is attributed to the high nutrient content in the figs of *Ficus* species in the Old World than that in the *Ficus* species of the New World (Snow 1980). The generalist fig eating birds reported are bubuls, cuckoos, woodpeckers, mouse-birds, turacos, cracids, phaeasants and several families of passerines while generalist fig eating mammals are certain primates, treeshres and carnivores. The generalist fig eating birds and mammals use do not rely heavily on figs but use them as a supplement to other fruit diets and other diets. Casual fig-eating animals are usually not frugivorous but use figs opportunistically depending on the aviailability of their normal food diet. These animals are gulls, shrikes, rollers, kingfishers, ibis and motmots (see Shanahan 2000).

Figure 1. *Ficus amplissima :* a. & b. Fruiting phase, c. *Eudynamys scolopacea* (male), d. *Eudynamys scolopacea* (female), e. & f. *Megalaima haemocephala*, g. *Merops orientalis*, h. *Halcyon smyrnensis*, i. *Tokus birostris*, j. *Dicrurus adsimilis*, k. *Dendrocitta vagabunda*.

In this study, it is observed that *F. amplissima* fruits are light green in the initial stage of development and purple or red when ripe producing smooth achenes (Figure 1a,b). Anonymous reports recorded that *F. amplissima* seeds are dispersed by Indian fruit bat, *Pteropus medius* (Order Chiroptera and Family Pteropodidae), birds and other mammals. *F. amplissima* here is not used as rooster tree species by bats and it is being semi-deciduous with partial cover of foliage during dry season presents figs openly for easy recognition by frugivores. Bat activity is totally absent here and only birds use figs of this species as food during dry season. The birds that used the figs as food source are *Eudynamys scolopacea* (Cuculiformes: Cuculidae) (Figure 1c,d), *Megalaima haemocephala* (Piciformes: Megalaimidae) (Figure 1e,f), *Merops orientalis* (Coraciformes: Meropidae) (Figure 1g), *Halcyon smyrnensis* (Coraciformes: Alcedinidae) (Figure 1h), *Tokus birostris* (Bucerotiformes: Bucerotidae) (Figure 1i), *Dicrurus adsimilis* (Passeriformes: Dicruridae) (Figure 1j) and *Dendrocitta vagabunda* (Passeriformes: Corvidae) (Figure 1k). The bird species composition indicates that birds of different families and orders rely on *F. amplissima* figs as food source at this time of the year. Upon arrival on the branch, they reach

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the fruit bearing part and pick up the fig with their bill and fly off to another tree of the same or different tree species for eating the pulpy part of the fig and drop the seeds while eating or through the excreta. In this way, these birds are involved in effective seed dispersal for *F. amplissima*. Hartwig (1993) reported that the birds with good colour vision tend to feed on red figs presented among foliage. In *F. amplissima*, the red figs are not covered by foliage during their ripening phase and it is for the birds to recognize the figs for feeding. It is not known whether the figs of *F. amplissima* are equally suitable as nutritious food for all visiting birds. However, the birds visiting this tree species in this forest ecosystem take advantage of figs as their nutriment source when other food resources are not available. Therefore, *F. amplissima* is a prominent dietary source for birds and may act as a keystone species in the deciduous forest ecosystem which is declared as a Forest Reserve by local government.

4. CONCLUSION

Ficus amplissima is a monoecious semi-deciduous tree species. The syconium-wasp association speaks of obligate mutualism and breakdown of this mutualism affects sexual reproduction in both tree and wasp species. Fruit commonly called as "figs" are purple or red and attract only birds in the study location. The figs ripe during dry season when most of the co-occurring tree species are leafless or in flowering. The study location being deciduous presents a food shortage or crisis for insect and verebrate fauna during dry season. At this time, the figs of this tree species provide food for bird fauna of different families and orders. Therefore, *F. amplissima* is most likely a keystone species for birds utilizing its figs during dry season. The study recommends to take steps for planting this tree species in this ecosystem in order to sustain frugivorous birds during dry season.

Authors contributions

Both authors contributed equally.

Ethical approval

Syconium-wasp association and ornithochory in *Ficus amplissima* Sm. (Moraceae) was observed in the work. The ethical guidelines are followed in the study for species observation & identification.

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Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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